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TITLE: EXPERIENCE WITH INSTALLATION AND OPERATION
OF DIGITAL ELECTRONIC BALANCES

AUTHOR(S):   William R. Severe, Charles C. Thomas, Jr.,
and Melvin M. Stephens

MASTER

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87545

EXPERIENCE WITH INSTALLATION AND OPERATION OF DIGITAL ELECTRONIC BALANCES

William R. Severe, Charles C. Thomas, Jr., and Melvin M. Stephens
University of California
Los Alamos Scientific Laboratory
Los Alamos, NM 87545 USA

Abstract

Los Alamos Scientific Laboratory is implementing a near real-time nuclear material control program. Digital electronic balances interfaced directly to a central computer are an important part of this program. Weighing errors are characterized and several methods of installation are discussed in terms of the impact on measurement errors.

Introduction

A major nondestructive assay measurement technique used in the Los Alamos Scientific Laboratory Plutonium Processing Facility is bulk weight and assay factor. The former is determined by balances and the latter is based on chemical analysis. This paper discusses the experience with the electronic balances installed in the gloveboxes including both the installation and precision and accuracy aspects. Remoting techniques measurement control and statistical analysis methods are presented. Results obtained for selected balances are included.

Materials and Methods

The DYMAC system uses commercially available digital readout electronic balances. These units have been modified to minimize the amount of electronics within the glovebox. The basic unit locates only the weighing pan and force-restoring mechanism within the glovebox. The weigh cell components are housed in a stainless steel compartment, as shown in Fig. 1, and have proven to be resistant to chemical corrosion and radiological damage. The electronics package shown in Fig. 2 is placed outside the glovebox and located in a position that facilitates operator interaction when a weighing is made. The electronics and electromechanical sections of the balance are connected by cable made up of six twisted pairs of wires with individual shielding. This arrangement plugs into the electronics and electromechanical packages with standard connectors. The cable penetrates the glovebox with a through-bulkhead 6-pin hermetically sealed receptacle. This remoting technique has some limitations. A weak electronic signal must be used which results in a maximum cable length of 20 feet. Also, due to the weak signal, movement of the connecting cable causes capacitance changes in the cabling sufficient to produce changes in the balance calibration.

An alternate remoting method results in improved signal transmission but less corrosion resistance. This technique moves the transducer board inside the electromechanical weight cell housing. This produces a stronger, more stable signal to the external electronics package. When this technique is coupled with a

strain-relieved direct connection of the cable at the weight cell and electronics packages, movement of the cable no longer affects balance calibration. This technique has been utilized in the DYMAC system where corrosion resistance was not a significant factor. For the corrosive environment, the basic remoting technique is preferred. A suitable potting technique for the transducer board would provide the optimal solution of both high corrosion resistance and good signal transmission characteristics.

The external electronics package features a digital readout for operator inspection and an option for retaining a measurement for direct transmission to the central computer. To retain a weight for transmission, the operator presses a "hold" button. This action latches the measured weight in the readout and prepares an interface to transmit data on command from the DYMAC computer. The "hold" feature is operative only when the balance reading has stabilized. The interface receives parallel BCD data from the balance and converts it to serial ASCII format. Data is then transmitted to the DYMAC computer by an optically isolated 20 mA current loop.

Provided that the weight cell and connecting cabling are immobilized when the basic remoting scheme is used, the precision and accuracy of the balances is independent of remoting technique.

There are three types of DYMAC electronic balances: 5.5 kg capacity readable to 0.1 gram, 5.5 kg capacity readable to 0.01 gram, and 15 kg capacity readable to 0.1 gram. The 5.5 kg balance types are identical except that the 0.01 gram readability model has an extra digit displayed.

DYMAC uses an on-line measurement control program to compile balance precision and accuracy data and to provide a daily check of balance performance. The measurement control program consists of four accuracy checks and one precision check per week. An accuracy check is done daily except for the day a precision check is made. The accuracy check consists of single weighings of NBS traceable reference weights at each of two levels (1 kg and 4 kg). The precision check consists of 5 independent weighings of each of the reference weights. The weight results are transmitted to the DYMAC computer by an operator initiated transaction through one of the interactive terminals.

The fundamental on-line control parameters are the t-parameter for accuracy and the F-parameter for precision. The t-parameter for a single measurement is

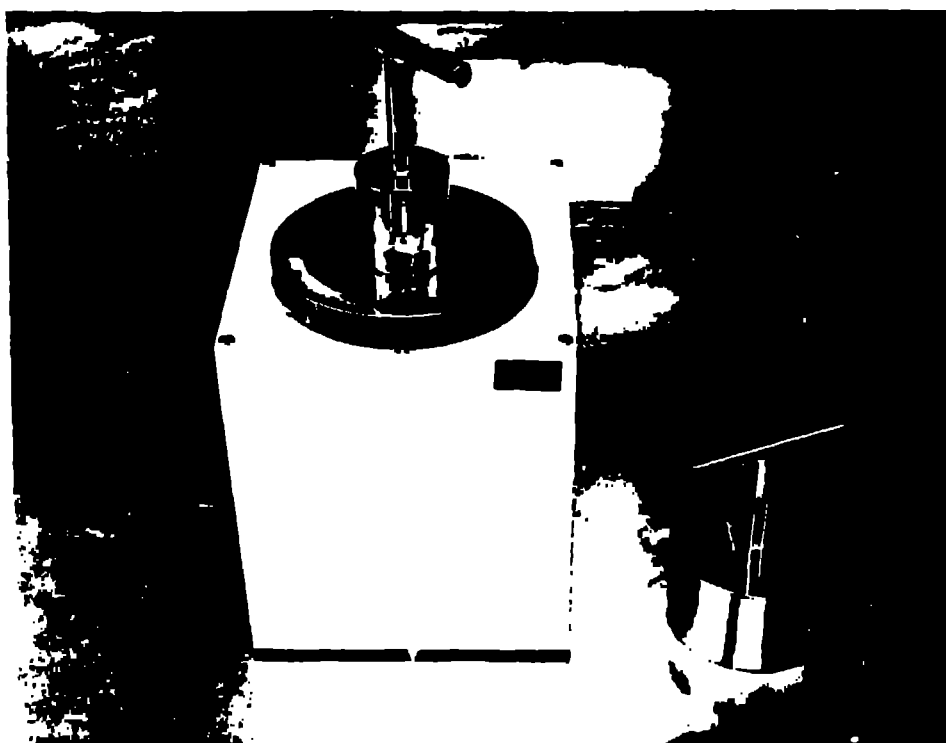$$\frac{W_j - W_o}{S_A} = \text{t-parameter}$$

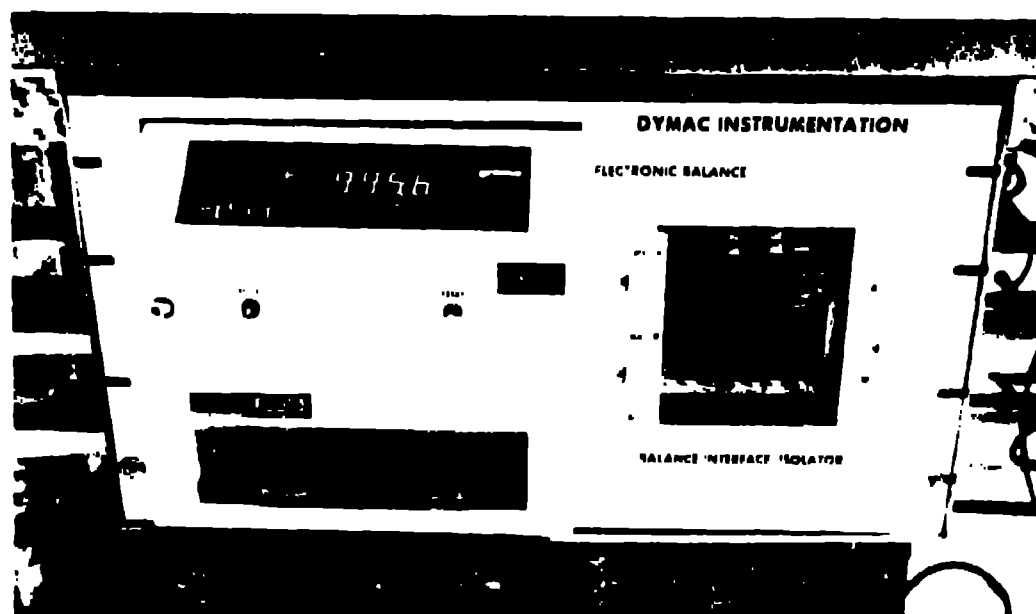Fig. 1. Electronic balance weight cell and reference weights.

DYMAC INSTRUMENTATION

ELECTRONIC BALANCE

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BALANCE INTERFACE ISOLATOR

Fig. 2. Balance electronic display.

where

W$_i$ is the measured weight

W$_0$ is the standard weight

S$_A$ is a historical standard deviation

For a single set of observations, the F-parameter is

$$\frac{S_i^2}{S_p^2} = \text{F-parameter}$$

where

S$_i^2$ is the variance of the set of observations

S$_p^2$ is the pooled variance of the last 15 weeks' observations.

The DYMAC computer calculates these parameters for each balance from the input data and compares the result to control limits based on appropriate degrees of freedom. These parameters are also calculated for the 5 day and 15 week average values and standard deviations. The 5 day and 15 week calculations are the basis of random and systematic error estimates.

Results

Data analysis has determined that the random error at the 1 kg reference weight is significantly lower than the random error at the 5 kg reference weight. This indicates that the random error for an electronic balance is proportional to mass. The random error variance can be described as the sum of an absolute error variance and a proportional error variance. A set of random errors for a typical 5.5 kg balance is 0.045 grams at the 1 kg level and 0.202 grams at the 5 kg level. For a typical 15 kg balance, the random errors are 0.050 grams at the 1 kg level and 0.232 grams at the 15 kg level. The error components associated with the electronic balance are far more between balances

to the extent that all balances are treated separately with regard to error calculation, control limit determination and error propagation.

The limit of error calculations for digital balances are quite complicated if treated rigorously. The two-component nature of the random error is a complicating factor. Also, a rigorous treatment would require measurement data to be bias corrected. Long term bias ranges from 0.02 grams to 0.12 grams per determination, and is a function of mass. However, since the random error and bias corrections are small relative to the 1 gram accountable unit, limit of error calculations are simplified by treating the random error as a single component include error and systematic errors are propagated in a manner appropriate for the bias correction not being made.

The electronic balances are very simple in terms of operator interaction. The tare bar, which tares out the weight on the balance pan with a single press, and the "hold" button for latching a weight for transmission to the DYMAC computer, are simple to use and conveniently located, as shown in Fig. 3. The balances have proven to be very durable. Not only is the electromechanical weight cell resistant to mechanical damage, it is far more tolerant of operator abuse than a comparable weight range knife edge system. The pan is supported on the weight cell by a tripod mechanism which is far from indestructible, but very tolerant of normal operator abuse and is not affected by loading the pan off-center.

Conclusions

To recapitulate, operating experience indicates that the remoted weight cell should include the transducer board when possible to avoid problems with signal transmission, and that hardwiring of the connecting cable to the weight cell and electronic readout is preferable to cable connectors. Measurement data demonstrates that measurement errors are proportional to weight and that small biases are correctable to calibrate out of the system. Maintenance of optimal balance performance requires a continuing measurement control program conducted by technically competent personnel. Finally, the electronic balances provide a simple and durable instrument for in-line weight measurement.

Figure ... [illegible caption]

List of Figures